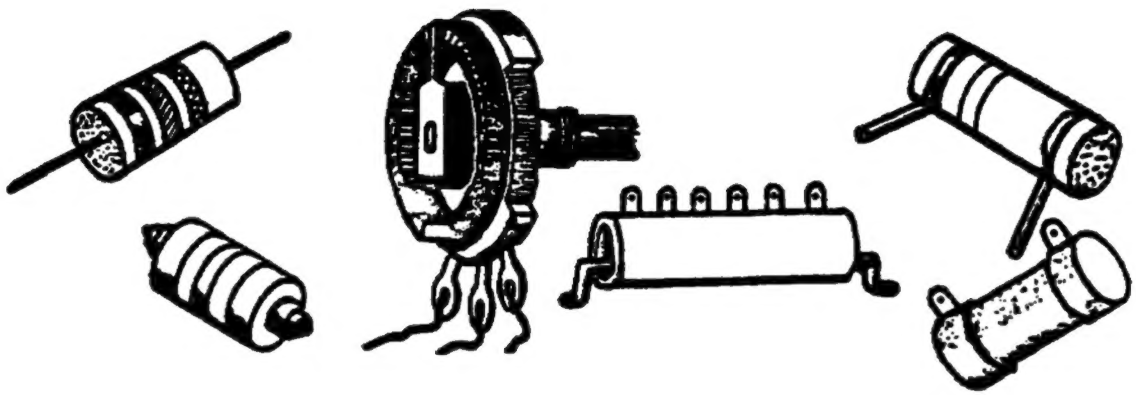
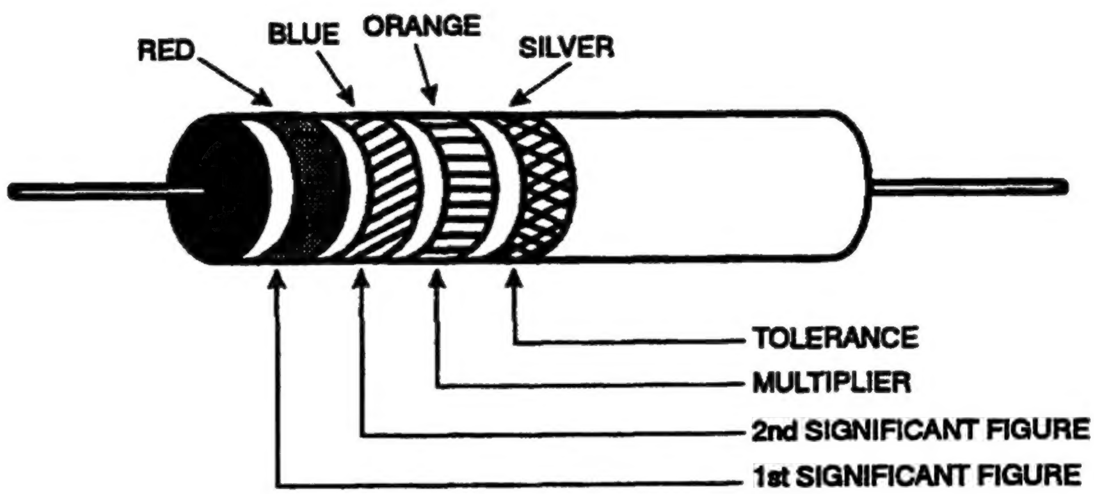
SUBCOURSE IT0340

EDITION A

US ARMY INTELLIGENCE CENTER

CONDUCTORS, RESISTORS, INSULATORS AND COLOR CODES





THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT
ARMY CORRESPONDENCE COURSE PROGRAM

AIPD
READINESS PROFESSIONALISM THRU GROWTH

CONDUCTORS, RESISTORS, INSULATORS, AND COLOR CODES

Subcourse Number IT0340

EDITION A

U.S. ARMY INTELLIGENCE CENTER
FORT HUACHUCA, AZ 85613-6000

3 Credit Hours

Edition Date: MAY 1996

SUBCOURSE OVERVIEW

This subcourse is designed to teach you the characteristics of conductors, insulators, and resistor, and to interpret the color codes of resistors.

There are no prerequisites for this subcourse, although, if this is your first training in electricity and electronics, you should complete subcourses IT0332 through IT0339 first.

This lesson replaces SA0710.

TERMINAL LEARNING OBJECTIVE

TASK: You will identify the types, classifications, and characteristics of conductors, insulators, and resistors, define them, recognize the schematic symbols for resistors, explain the rating factors for resistors, and interpret resistor color codes.

CONDITION: Given color code charts, schematic diagrams, and pictures of resistors.

STANDARD: To demonstrate competency of this task, you must achieve a minimum of 70% on the subcourse examination.

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LESSON

CONDUCTORS, RESISTORS, INSULATORS, AND COLOR CODES

OVERVIEW

LESSON DESCRIPTION:

Upon completion of this lesson, you will know the characteristics of conductors, insulators, and resistors, and how to interpret the color codes of resistors.

This lesson replaces SA0710.

TERMINAL LEARNING OBJECTIVE:

ACTION: Identify the types, classifications, and characteristics of conductors, insulators, and resistors, define them, recognize the schematic symbols for resistors, explain the rating factors for resistors, and interpret resistor color codes.

CONDITION: Given color code charts, schematic diagrams, and pictures of resistors.

STANDARD: To demonstrate competency of this task, you must achieve a minimum of 70 percent on the subcourse examination.

1A

CONDUCTORS, RESISTORS, INSULATORS, AND COLOR CODES

So far in your study of dynamic electricity and Ohm's law, you have learned that three things are necessary to complete an electrical circuit. They are a source of electrons, a conductor or "path" for the electrons to move along, and an EMF or “force” to push the electrons along the conductor.

At this time, we are mainly interested in the material that acts as a path for the electrons, or as it is called in electrical circuits, the conductor.

A conductor is a material that offers small opposition to the flow of electrons.

Now, let's go back for a moment and see what you remember from the lesson on dynamic electricity.

The reason a material is a good conductor is because:

its atoms can easily accept and give up electrons. Page 1-4A

it does not readily accept or give up electrons. Page 1-9A

1B

YOUR ANSWER: To supply a source of free electrons.

(From P1-4A)

Sorry, bad guess. Remember, there were three things necessary to complete an electrical circuit. They were a source of electrons, a conductor or “path” for the electrons to move along, and a force to push the electrons through the conductor. Now, go back to Page 1-4A and try again.

2A

YOUR ANSWER: The atomic structure of a material is the greatest factor in determining its resistance.
(From P1-8A)

Correct. That is the first and probably the most important of the four factors that determine the resistance of a material. But let's not underrate the other three. For instance, the next factor is the length of the conductor. It just stands to reason that if a conductor one foot long has a certain amount of resistance, then a conductor made of the same material but two feet long would have more resistance. In other words, the longer the conductor, the more resistance it offers to current flow. The next factor is the cross-sectional area of the conductor (don't be confused by the big words, we simply mean how big around it is) works the opposite way. A conductor one foot long and 1/4 inch in diameter has a certain resistance. A conductor made of the same material, one foot long but 1/2 inch in diameter, would have less resistance. Just like a water pipe. It's harder to get the same volume of water through two pipes when one pipe is smaller than the other. OK? Now answer the following question:

A conductor four inches long and one inch in diameter has a resistance of 8 ohms. If we were to stretch this conductor to eight inches, with the diameter decreasing to one-half inch, the resistance would

increase.	Page 1-3B
decrease.	Page 1-6A
stay the same.	Page 1-108B

2B

YOUR ANSWER: Resistor "A".
(From P1-7A)

Wrong. We just said that resistors may be small in size-- 1 inch in length and 1/4 inch in diameter, yet range in resistance from less than one ohm to more than several million ohms. The physical size of a resistor has a lot to do with the power rating (which we'll go into later), but practically nothing to do with the amount of resistance. Go back to Page 1-7A and choose the correct answer.

3A

YOUR ANSWER: Resistor "A".
(From P 1-25)

Come on now. You know better than that. Resistor "A" might offer more resistance than resistor "B" but it is much smaller. Since physical size is the main determining factor for power rating, resistor "B" would have the highest power rating. Go back to Page 1-25 and try again.

3B

YOUR ANSWER: Resistance would increase.
(From P1-2A)

Very good. The resistance is directly proportional to the length and inversely proportional to the cross-sectional area.

So far, we have covered three of the factors determining resistance. They are the type of material used, the length of the conductor, and the cross-sectional area. The fourth and last factor is the temperature. As you apply heat to a conductor, random electron movement increases. This increase in electron movement causes more collisions between the electrons and these collisions cause the resistance to increase. However, there are some materials that decrease in resistance when they are heated. When heat is applied to these materials, additional electrons are freed at a greater rate than the increase in collisions between electrons. So the resistance decreases with an increase in temperature. Such substances are the exception, rather than the rule, and they are said to have a negative temperature coefficient. Carbon is an example of a substance with a negative temperature coefficient.

Which of the below listed items determine the resistance of a conductor?

The type of material used and the temperature.	Page 1-7B
The length and the cross-sectional area.	Page 1-16B
Both of the above.	Page 1-21A

4A

YOUR ANSWER: Its atoms can easily accept and give up electrons.
(From P1-1A)

Good for you. That's exactly what we wanted. In order for a material to be a good conductor, it must have a good supply of free electrons and be ready, willing, and able to accept more and/or give up what has.

We said that a conductor is a material that offers small opposition to the flow of electrons. So actually, what we are saying is that a good conductor will readily accept or give up its valence (free) electrons. Some of the more common materials that will do this for us are gold, silver, copper, and aluminum.

Now, let's go back over something else we have already learned. Complete the following statement:

The purpose of a conductor is

to supply a source of free electrons.	Page 1-1B
to provide a path for the electrons to travel around the circuit.	Page 1-6B
to provide a force to move the electrons around the circuit.	Page 1-9B

4B

YOUR ANSWER: The atomic structure of a material has very little effect on its resistance.
(From P1-8A)

Now wait a minute. You must have misunderstood. We said there are four factors that determined the resistance of a material. And we also said the most important of these four factors is the atomic structure. The atomic structure determines if a material has free electrons, and how many free electrons it has. This number of free or valence electrons is the major factor in determining the resistance of a material. Go back to Page 1-8A and choose another answer.

5A

YOUR ANSWER: Yes. Electrons can be made to flow, even in insulators.
(From P1-19B)

Correct. With a sufficient force, electrons will flow in any material. First of all, there is no such thing as a perfect insulator, so there is always some electron movement. When we apply enough force (voltage) to cause an intense flow (avalanche) of electrons through an insulator, we have reached the insulator's breakdown point. The insulator is now acting like a conductor and the result is generally the destruction of the insulator.

Effects of insulator breakdown are burning or charring of combustible material and breaking or cracking of noncombustible materials. These effects are very obvious, so your nose and your eyes can be valuable tools in troubleshooting electronics gear.

We have one final item to cover in this lesson. Resistors. No, not resistance, RESISTORS. But before we get into a discussion on resistors, let's drop back and see what you remember about resistance. Choose the correct definition for resistance.

Resistance is the opposition offered to the flow of electrons.	Page 1-7A
Resistance is a measure of the opposition of a particular volume of material at a temperature of 20 degrees centigrade.	Page 1-22A

5B

YOUR ANSWER: The specific resistance of a material is the resistance of a unit volume of that material at a temperature of 20 degrees centigrade.
(From P1-12B)

Absolutely true BUT what about the other three statements? Aren't they also correct? Perhaps you didn't bother to read more than the first statement. Go back to Page 1-12B and read the rest of them. See if there isn't a more correct answer.

6A

YOUR ANSWER: Resistance would decrease.
(From P1-2A)

Maybe you didn't understand the question. If a conductor four inches long and one inch in diameter had a resistance of 8 ohms and we stretched it out to 8 inches, it would be longer. Since the resistance varies directly with the length and we increased the length, the resistance would have to increase. Also, if we stretched it out, its diameter would decrease from one inch down to 1/2 inch. Since the resistance varies inversely to its cross-sectional area and we made the cross-sectional area smaller, we would cause the resistance to become greater or increase. Now go back to Page 1-2A and choose another answer.

6B

YOUR ANSWER: To provide a path for the electrons to travel around the circuit.
(From P1-4A)

Outstanding. You're doing fine. Now we know some of the more common types of materials that make good conductors, such as gold, silver, copper, and aluminum, and the purpose of a conductor. But don't get carried away with that "good" conductors. There is no such animal as a perfect conductor. All materials offer some opposition to electron (current) flow. This opposition to current flow is called resistance. Or, stated the other way, resistance is the opposition offered to the flow of electrons. The unit of measurement for resistance is the OHM, which is represented by the Greek letter OMEGA, written Ω. In other words, 1Ω of resistance is equal to 1 Volt of potential divided by 1 Amp of current: $1\Omega = \frac{1V}{1A}$

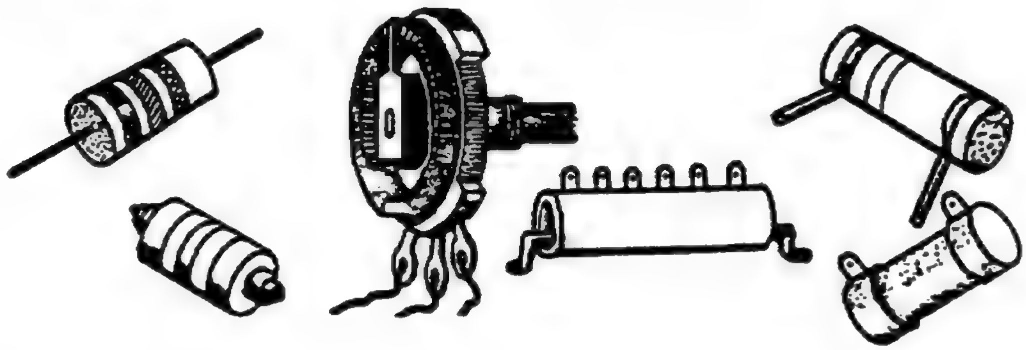
Now, which of the following statements is true?

Resistance is a measure of the amount of current flow in a conductor.	Page 1-15B
Resistance is the opposition to current flow in a conductor.	Page 1-8A

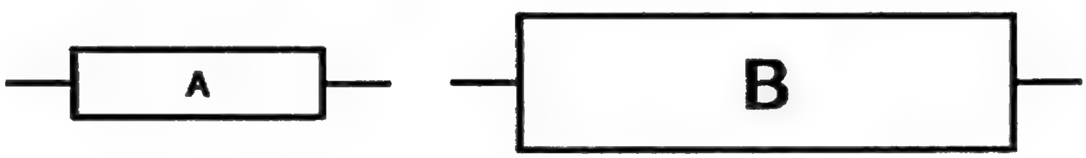
7A

YOUR ANSWER: Resistance is the opposition offered to the flow of electrons.
(From P1-5A)

Exactly! A resistor is a device or component used to introduce opposition to current flow in a circuit. Resistors are designed to have specific amount of opposition to current flow, and may be of many different sizes and shapes. The size and shape of a resistor will not determine its value however. One as small as 1 inch long and 1/4 inch in diameter may vary in value from less than one ohm to as much as several million ohms. The illustration below shows a few of the various resistors used in electrical and electronic circuits.



Which of the resistors below has the more resistance?



Resistor A.	Page 1-2B
Resistor B.	Page 1-13A
Cannot tell.	Page 1-17A

7B

YOUR ANSWER: The type of material and the temperature.
(From P1-3B)

You have the right idea but you didn't go far enough. Remember, now, we said there were four factors that determine the resistance of a conductor. They are the type of material used, the length, the cross-sectional area, and the temperature. Now let's go back to Page 1-3B and read the question again.

8A

YOUR ANSWER: Resistance is the opposition to current flow in a material.
(From P1-6B)

Very good. Now we are getting somewhere. We know what resistance is. Now let's talk about some of the things that determine resistance. There are four more factors that determine resistance. They are the type of material used, the length of the conductor, the cross-sectional area, and the temperature of the conductor. We'll go back now and take them one at a time.

The first is the type of material used. This is the biggest single factor in determining resistance. It all goes back to the atomic structure of materials. Materials such as gold, silver, copper, and aluminum which have one, two, or three valence electrons make the best conductors. The valence electrons of these materials are constantly moving at random from one atom to another. So, if we apply an external force, we can move these electrons in a desired direction with very little opposition (resistance).

Choose the correct statement.

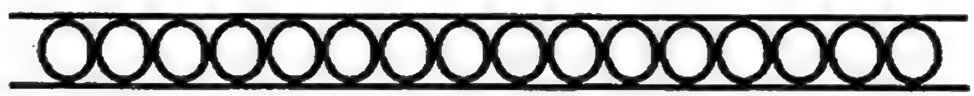
The atomic structure of a material is the greatest factor in determining its resistance.	Page 1-2A
The atomic structure of a material has very little effect on its resistance.	Page 1-4B
The atomic structure of a material is the least important of the four factors that determine a material's resistance.	Page 1-15A

9A

YOUR ANSWER: It does not readily accept or give up electrons.
(From P1-1A)

OooooooooPs. I guess our program on dynamic electricity wasn't as good as we thought.

The question was - the reason a material is a good conductor is because: Do you remember the illustration with the pipe and the ping pong balls?



If you were to push another ball into one end of the pipe, it would cause one to pop out a the opposite end. This is exactly what happens in a conductor. When an electron is forced into one end of a conductor, an electron pops out the opposite end. Not the same electron of course, but the result is the same. You put an electron in at one end and get one out at the other end. Now the easier a material will accept and give up these electrons, the better conductor it makes. OK? Now, let's go back to Page 1-1A and try the other answer.

9B

YOUR ANSWER: To provide a force to move the electrons around the circuit.
(From P1-4A)

Now you know better than that. There are three things required to complete an electrical circuit. They are a source of electrons, a conductor or “path” for the electrons to travel around the circuit, and a force to push the electrons through the conductor. Remember, back in the lesson on dynamic electricity, we said we had a force to push the electrons through the circuit. It was called EMF (electromotive force) and it was supplied by a battery or a similar device. Now go back to Page 1-4A and read the question again.

10A

YOUR ANSWER: The specific resistance of a material is the resistance of any amount of that material at 20 degrees centigrade.
(From P1-21A)

No. You have the right temperature but the rest of the answer is wrong. Remember, resistance is determined by the length and cross-sectional area too. What this answer implies is that the resistance of a copper wire one foot long and one inch in diameter would be the same as the resistance of a copper wire ten feet long and two inches in diameter, and we both know that this isn't true. Specific resistance is the resistance of a particular amount of a material at a temperature of 20 degrees centigrade. Now go back to Page 1-21A and choose the correct answer.

10B

YOUR ANSWER: The resistance would stay the same.
(From P1-2A)

Maybe you didn't understand the question. If a conductor four inches long and one inch in diameter had a resistance of 8 ohms and we stretched it out to 8 inches, it would be longer. Since the resistance varies directly with the length of a conductor and we made it longer, the resistance would have to increase. Also, when we stretched it out, its diameter decreased. Since the resistance varies inversely with the cross-sectional area and we decreased the cross-sectional area, we caused the resistance to increase. Go back to Page 1-2A and choose another answer.

11A

YOUR ANSWER: No. It is not possible to cause electron flow in an insulator.
(From P1-19B)

Hold on a minute. Let's stop and think about this. Haven't you ever seen sparks when you pulled the plug from an electric socket? These sparks are nothing more than electron flow and they are flowing through air. And we said air was an insulator. Or take the spark plug on a car. Doesn't the spark jump from one contact to the other? The only way that it can get there is to travel through air. Again, air is an insulator. Go back to Page 1-19B and read the question again.

11B

YOUR ANSWER: Cost, temperature, and melting point.
(From P1-20B)

Sorry, bad guess. Two of the items are right. They are the cost and the melting point, but temperature is wrong. You are getting the considerations for choosing a conductor confused with the factors that determine the resistance of a material. Temperature was one of the factors that determine the resistance of a conductor. Remember, conductors have to be joined together in order to construct a piece of equipment, so one of the things to consider would have to be the ability to be fused or soldered.

Go back to Page 1-20B and choose the correct answer.

12A

YOUR ANSWER: The two types of resistors are metallic and wire-wound.
(From P1-17A)

Shame. A wire-round resistor is an example of a metallic-type resistor. Also, an axial-lead resistor is an example of a nonmetallic type of resistor. Go back to Page 1-17A and choose the correct answer.

12B

YOUR ANSWER: Melting point, cost, and the ability to be fused.
(From P1-20B)

Right. That's three of the five items to consider when selecting a conductor. The next item is the weight. Today, with more and more electronic gear being put in aircraft, weight has become a very important item. Copper is the second best metallic conductor and aluminum is the fourth best, but when considering a conductor to use in aircraft, the lighter weight of aluminum more than offsets the difference in conductivity.

The last item is elasticity (good spring action). Some conductor applications such as meter springs and switch spring contacts require a material with good elasticity. Phosphor bronze is a good example of this type of elasticity. So far, we have talked about conductors and the five factors affecting the choice of a conductor. We have also learned about the four items that determine the resistance of a conductor and, finally, the meaning of the specific resistance of a material. Let's take a check on how much you have learned.

Which of the following statements are correct?

The specific resistance of a material is the resistance of a unit volume of that material at a temperature of 20 degrees centigrade.	Page 1-5B
The five items affecting the choice of a conductor are cost, ability to be fused or soldered, melting point, weight, and elasticity.	Page 1-14B
The four factors determining the resistance of a conductor are the type of material, temperature, length, and the cross-sectional area.	Page 1-18A
All the above statements are correct.	Page 1-19B

13A

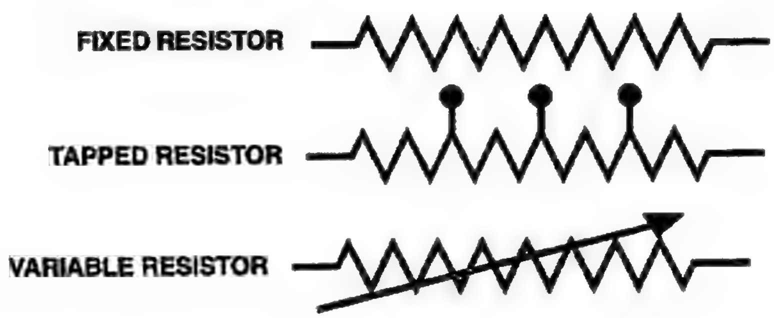
YOUR ANSWER: Resistor "B".
(From P1-7A)

Wrong. We just said that resistors may be small in size-- one inch in length and 1/4 inch in diameter, yet range in resistance from less than one ohm to more than several million ohms. The physical size of a resistor has a lot to do with the power rating, (which we'll go into later), but practically nothing to do with the amount of resistance. Go back to Page 1-7A and choose the correct answer.

13B

YOUR ANSWER: Fixed, tapped, and metallic.
(From P1-24A)

Not so. Fixed and tapped are two classifications of resistors but metallic is a type of resistor. The two types of resistors were metallic and nonmetallic, and the three classifications of resistors, along with the schematic symbol for each, are listed below.



Go back to Page 1-24A and choose the correct answer.

14A

YOUR ANSWER: True.
(From P1-16A)

Hey! Not so! What about the times when we want the conductor to offer a fairly high resistance so that it will heat up? Like, for instance, your mom's electric stove, or her toaster, or perhaps the soldering iron you have been learning to use. On the other hand, there are many times when we want the lowest possible resistance; for example, the wires connecting the components in your radio or the high-power transmission lines that run across the country. So, you see, the purpose of the conductor would dictate the type of material used. Now go back to Page 1-16A and choose the correct answer.

14B

YOUR ANSWER: The five items affecting the choice of a conductor are cost, ability to be fused or soldered, melting point, weight, and elasticity.
(From P1-12B)

Very true BUT what about the other three statements? Aren't they also correct? Isn't the definition of specific resistance right and the four factors determining the resistance of a conductor also correct? Go back to Page 1-12B, read them again, and choose the correct answer.

15A

YOUR ANSWER: The atomic structure of a material is the least important of the four
(From P1-8A) factors that determine the resistance of a material.

Shucks. You picked the wrong answer. We said that of the four factors that determine the resistance of a material, the atomic structure is the most important one. The atomic structure determines the number of free or valence electrons a material has. Materials which have one, two, or three valence electrons, and can easily give them up or accept more, offer small resistance to current flow and, therefore, make good conductors. Go back to Page 1-8A and choose another answer.

15B

YOUR ANSWER: Resistance is a measure of the amount of current flow in a material.

Slow down. You are going too fast and not reading the material. If you read the answer you picked carefully, you will find that it says "resistance is a measure of the amount of current flow" and you and I both know that isn't so. An ampere is the unit of measurement for current flow. Go back to Page 1-6B and try again.

16A

YOUR ANSWER: The specific resistance of a material is the resistance of a unit volume of
(From P1-21A) of that material at a temperature of 20 degrees centigrade.

Outstanding. The unit volume for metallic conductors is a conductor one foot long and one mil (.001 inch) in diameter and the unit volume for nonmetallic conductors is a cube one centimeter long and one centimeter wide.

Now that we know all about resistance, lets go into some of the things that affect the selection of the conductor we use. There are many different applications for conductors. Sometimes we simply want a conductor to provide a low-resistance path for electrons to travel around the circuit. At other times, we might want the conductor to offer fairly high resistance so that it will heat; up for example, toasters, electric heaters, and soldering irons. At other times, we might require elasticity (good spring action) and there is always the big item, COST. The five items that we will consider when selecting a conductor are: cost, ability to be fused or soldered, melting point, weight, and elasticity.

Is the following statement true or false?

The first consideration when choosing a conductor is to use a material that has the lowest specific resistance.

True. Page 1-14A

False. Page 1-20B

16B

YOUR ANSWER: The length and the cross-sectional area.
(From P1-3B)

You have the right idea, but you didn't go quite far enough.

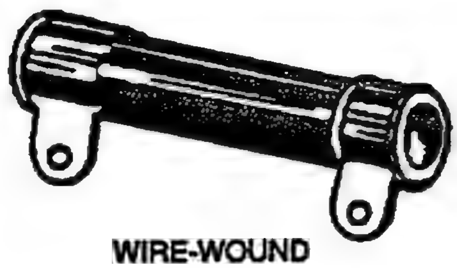
Remember, we said that there are four factors which determine the resistance of a conductor. They are the type of material used, the length, the cross-sectional area, and the temperature. Now, go back to Page 1-3B and read the question again.

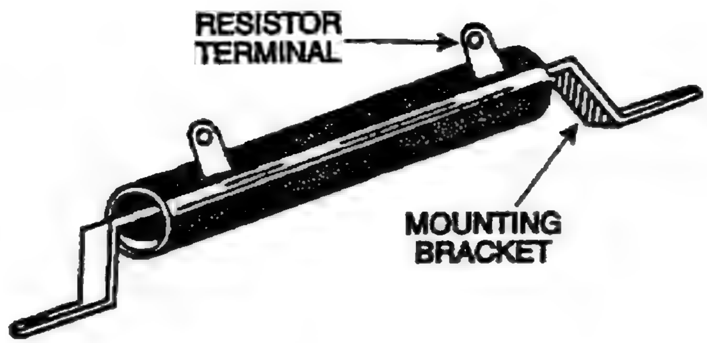
17A

YOUR ANSWER: Cannot tell.
(From P1-7A)

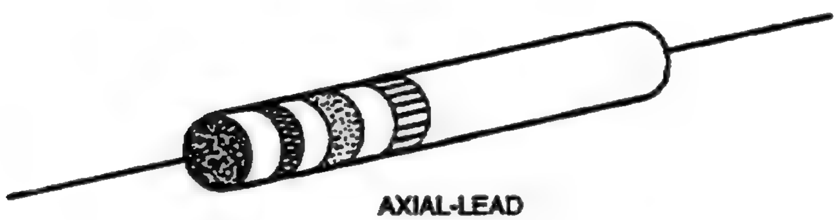
Good for you. It is impossible to tell the resistance of a resistor, just from the physical size.

There are two distinct types of resistors. They are metallic and nonmetallic. Metallic or metal resistors are usually made of a metal conductor wound around a tube of insulative material. They are often called wire-wound resistors. Metallic or wire-wound resistors generally are used when an extremely accurate amount of resistance is required and/or when there is to be a high power requirement. Below are examples of wire-wound resistors.





Nonmetallic resistors are usually made of a mixture of carbon and clay. The most common method of construction for nonmetallic resistors results in what is called the axial-lead resistor. A mixture of carbon and clay is pressed inside a tube of insulating material. The wires are bonded to each end of the carbon-clay mixture and the ends of the tube are sealed. Below is an example of an axial-lead resistor.



The two types of resistors are

metallic and wire-wound.	Page 1-12A
axial-lead and nonmetallic.	Page 1-20A
metallic and nonmetallic.	Page 1-29

18A

YOUR ANSWER: The four factors determining the resistance of a conductor are the type of material used, temperature, length, and the cross-sectional area.
(From P1-12B)

Quite true BUT what about the other three statements? Aren't they also correct? Isn't the definition for specific resistance correct and the five items affecting the choice of a conductor correct? Go back to Page 1-12B and read them again.

18B

YOUR ANSWER: The specific resistance of a material is the resistance of that material at 30 degrees centigrade.
(From P1-21A)

No, no, a hundred times NO. You don't even have the right temperature; also, there isn't any particular amount of material stated. This answer implies that a piece of copper wire one foot long and one inch in diameter would have the same resistance as a piece of copper wire ten feet long and two inches in diameter, and we both know that this isn't true. Specific resistance is the resistance of a particular amount of a material at a temperature of 20 degrees centigrade. Now go back to Page 1-21A and choose the correct answer.

19A

YOUR ANSWER: There are three types and two classifications of resistors.
(From P1-29A)

I'm afraid you are a little confused. Let's try it again. There are two types of resistors. They are metallic and nonmetallic. There are three classifications of resistors. They are fixed, tapped, and variable resistors. Now go back to Page 1-29A and try it again.

19B

YOUR ANSWER: All the above statements are correct.
(From P1-12B)

Perfect. You have learned everything we have covered so far. But don't pat yourself on the back yet, because we still have more to cover. We now have conductors, with their electrons galloping along through them, but what happens when a conductor touches something it isn't supposed to? Like the ground, or maybe you? If it happens to be you, it results in electrons leaving the conductor and traveling through you to ground. This results in a little effect called electrical shock. As you already know, this can be fatal, so we need something to isolate our conductors. We do this with <u>insulators</u>.

An electrical insulator is a material which is very reluctant to permit electron flow. An insulator has electrons just as all materials have, but it has practically no free electrons. The valence electrons have combined with other valence electrons to complete the valence shell, leaving virtually no free electrons available. <u>Hard rubber</u>, <u>glass</u>, <u>bakelite</u>, <u>porcelain</u>, <u>varnished fabric</u>, <u>dry air</u>, <u>oil</u>, and <u>mica</u> are examples of good insulating materials.

Do you think it is possible to cause electron flow, even in an insulator?

Yes.	Page 1-5A
No.	Page 1-11A

20A

YOUR ANSWER: The two types of resistors are axial-lead and nonmetallic.
(From P1-17A)

Shame. An axial-lead resistor is an example of a nonmetallic type of resistor. Also, a wire-wound resistor is an example of a metallic type of resistor. Go back to Page 1-17A and choose the correct answer.

20B

YOUR ANSWER: False.
(From P1-16A)

Good. You are still on the right track. Now let's go back and consider the five factors that determine the choice of a conductor. We'll take them one at a time. First, we'll talk about cost. That item pretty well explains itself. Silver is the best metallic conductor there is, but just imagine the cost of a normal everyday radio if it had 200 feet of silver wire inside of it. However, let's look at copper. It’s almost as good a conductor as silver, and the cost is only a fraction as much. OK, so much for cost. The next of our five considerations was the ability to be fused. In the construction of electronic gear and electrical appliances, there are thousands of places where the conductors have to be joined together. The standard way of joining these conductors together is by soldering. Therefore, for ease of construction and maintenance, the material would have to be easily soldered. Copper is very easy to solder.

The next of our five items was the melting point. Here, again, we would have to consider the place where we were going to use the conductor. If we wanted a fuse, we would use a material that had a low melting point. If we were making a light bulb filament or an element for an electric toaster, we would want a material with a high melting point.

Complete the following statement:

Of the five factors determining the choice of a conductor, the three we have talked about so far are

cost, temperature and melting point.	Page 1-11B
melting point, cost, and the ability to be fused.	Page 1-12B
ability to be fused, cost, and the length.	Page 1-23A

21A

YOUR ANSWER: Both of the above.
(From P1-3B)

Excellent. You now know what resistance is, the standard symbol for resistance (R), the unit of measurement for resistance (ohm), the abbreviation for that unit of measurement (Ω), and finally the four factors that determine resistance.

There is one more item to be discussed while we are on the subject of resistance, and that is specific resistance. Don't let the big words scare you. It's really very simple. All materials are classified according to the amount of opposition they offer to current flow. This opposition for any particular material is called its specific resistance. The standard of measure for all metallic conductors is the resistance in ohms of a conductor that is one foot long and one mil (.001 inch) in diameter. Since resistance varies with temperature, 20 degrees centigrade has been set as the temperature at which specific resistance is measured. The standard of measure of nonmetallic conductors is the centimeter cube. Stated in plainer words, the specific resistance of a nonmetallic conductor is the amount of resistance, face to face, of a cube of that material, one centimeter long and one centimeter square. Again, a temperature of 20 degrees centigrade has been set as the standard temperature for measuring specific resistance. But don't forget that the most important factor in determining the specific resistance of a material is the atomic structure of that material. Pick the correct statement.

The specific resistance of a material is the resistance of any amount of that material at 20 degrees centigrade.	Page 1-10A
The specific resistance of a material is the resistance of a unit volume of that material at a temperature of 20 degrees centigrade.	Page 1-16A
The specific resistance of a material is the resistance of that material at 30 degrees centigrade.	Page 1-18B

22A

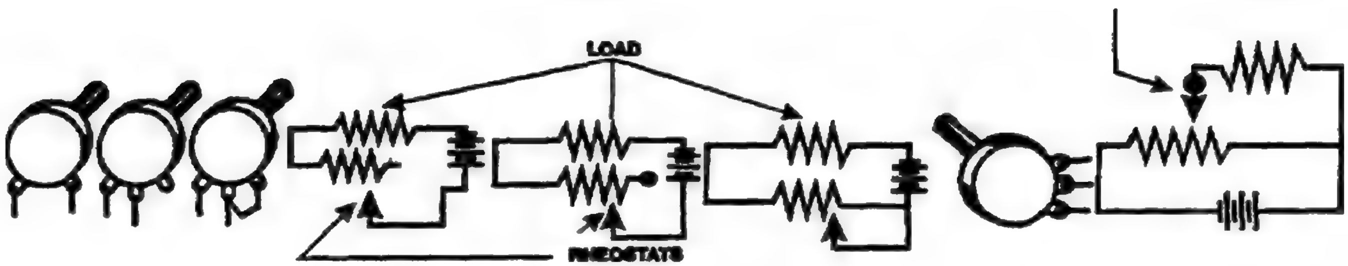
YOUR ANSWER: Resistance is a measure of the opposition of a particular volume of material at a temperature of 20 degrees centigrade.

NO! NO! NO! That is part of the definition of specific resistance. The full definition goes like this: The specific resistance of a material is the resistance of a unit volume of that material at a temperature of 20 degrees centigrade. Now go back and read the statements on Page 1-5A again.

22B

YOUR ANSWER: Fixed, tapped, and variable is exactly right. DON'T FORGET THE
(From P1-24A) SCHEMATIC SYMBOLS!

Variable resistors are of two kinds, RHEOSTATS or POTENTIOMETERS. Some variable resistors have only two terminals and these can only be used as rheostats. A three-terminal variable resistor connected as a rheostat has only two leads connected to the electrical circuit to adjust the current flow in a circuit or a portion of a circuit.



If the three terminals of a variable resistor each connect to different parts of a circuit, it is connected as a potentiometer. A potentiometer does not vary the total resistance between the terminal ends; instead, it varies the amount of resistance between each end and the center contact. The potentiometer is usually smaller in physical size than a rheostat and its purpose is to vary the amount of voltage applied to an electrical device. Essentially, it is a voltage divider.

Complete the statements below by filling in the blanks.

a. The two kinds of variable resistors are the________________________and_____________________.

b. The purpose of a rheostat is to adjust the____

____.

c. The purpose of a potentiometer is to vary the____

____.

(Continued on Page 1-25)

23A

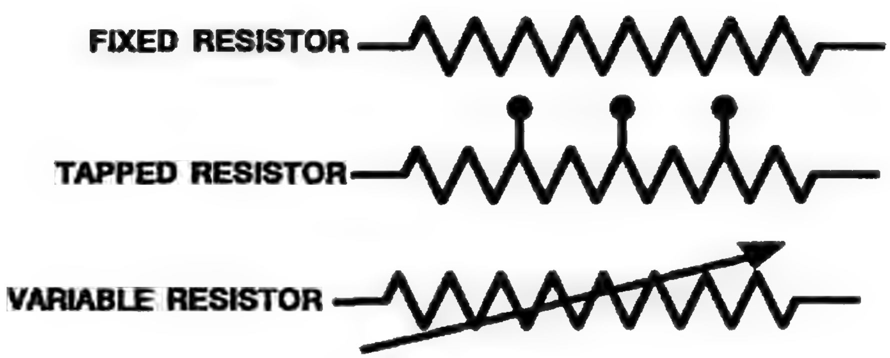
YOUR ANSWER: Ability to be fused, cost, and the length.
(From P 1-20B)

Now you know better than that. The ability to be fused and the cost are fine, but the length is one of the factors that determine the resistance of a conductor. How about the melting point? Doesn't that have something to do with the choice of a conductor? Remember if you wanted a fuse, you would use a material with a low melting point, and if you were building a light bulb filament, you would use a material with a high melting point. Now, go back to Page 1-20B and choose the correct answer.

23B

YOUR ANSWER: Metallic, nonmetallic, and variable.
(From P1-24A)

Not so. Metallic and nonmetallic are the two types of resistors. The three classifications of resistors, along with the schematic symbol for each, are listed below.



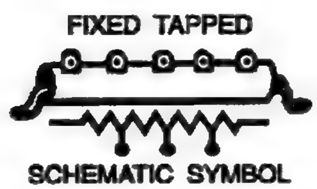
Go back to Page 1-24A and choose the correct answer.

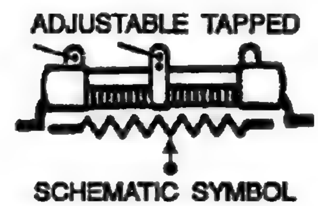
24A

YOUR ANSWER: There are two types and three classifications of resistors.
(From P1-29A)

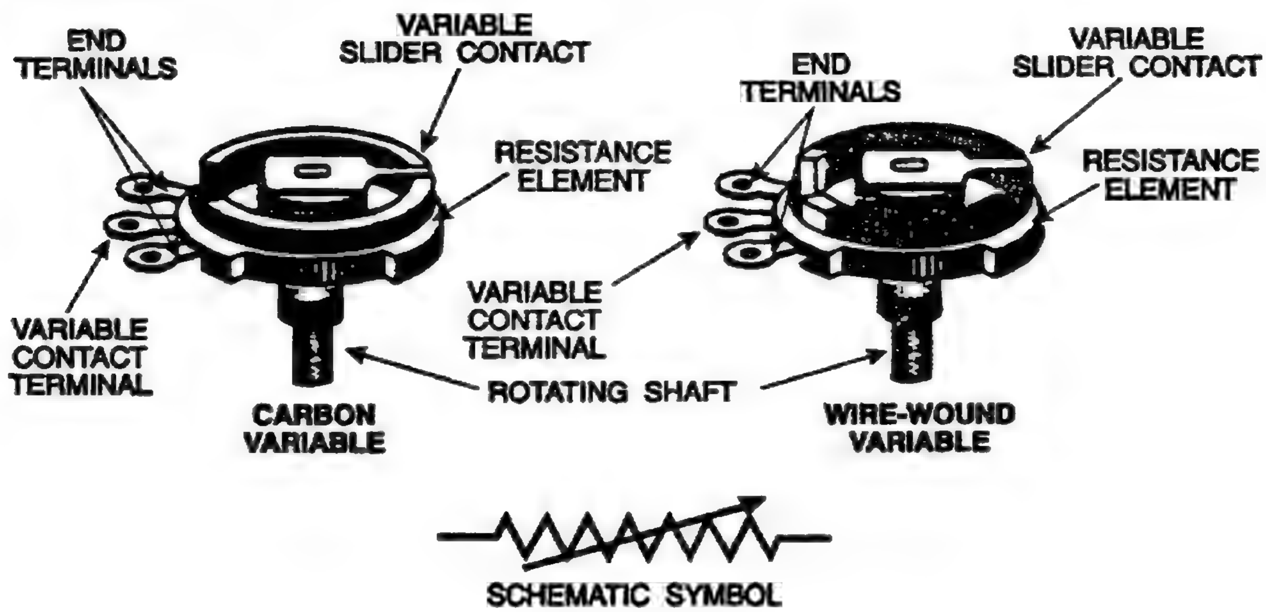
You are correct.

We've already discussed one classification of resistors. That was the fixed resistor. The next classification is the tapped resistor. This resistor is manufactured with a fixed value of resistance from end to end having either fixed taps placed at intervals on the resistor that will give fixed resistances, or an adjustable tap that can be secured on the resistor when the desired ohmic value has been established. Below are examples of the fixed-tap and adjustable-tap resistors and their schematic symbols.





The last classification of resistors is the variable resistor. It can be either metallic or nonmetallic. It is constructed to be continuously variable from zero to its maximum resistance. Below are two cutaway examples of variable resistors and the schematic symbol for a variable resistor.



The three classifications of resistors are

fixed, tapped, and metallic	Page 1-13B
metallic, nonmetallic, and variable	Page 1-23B
fixed, tapped, and variable	Page 1-22B

Answers for Page 1-22:

a. rheostat and potentiometer (any order).

b. current flow in a circuit or a portion of a circuit.

c. amount of voltage applied to an electrical device, or act as voltage divider.

Resistors are rated both in ohms of resistance and maximum power (watt). The ohmic value of a resistor is the opposition it will offer to the flow of electrons. Most resistors usually have the resistance value in ohms or the wattage value printed or stamped on the body of the resistor.

Wattage ratings of resistors indicate the ability of a resistor to dissipate heat. This simply means how much power (usually in the form of heat) the resistor will stand before it is damaged or destroyed.

High-wattage resistors are constructed larger in size than low-wattage resistors to provide greater surface for dissipation of the heat created by current passing through the resistor.

1. Select from the list below, the two factors that determine the rating of a resistor. Circle the letter in front of your answer.

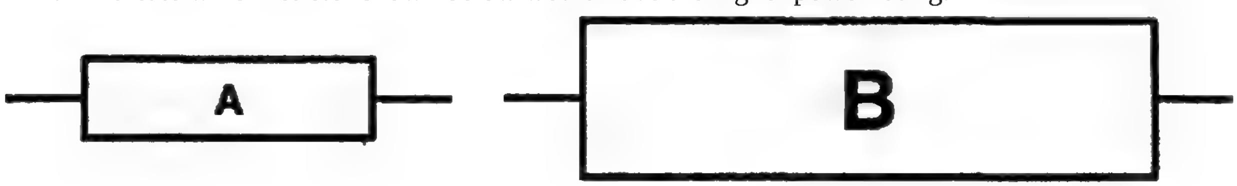
   a. Volts and watts

   b. Amps and watts

   c. Ohms and watts

   d. Amps and ohms

2. Indicate which resistor shown below would have the higher power rating.



(Continued on Page 1-26)

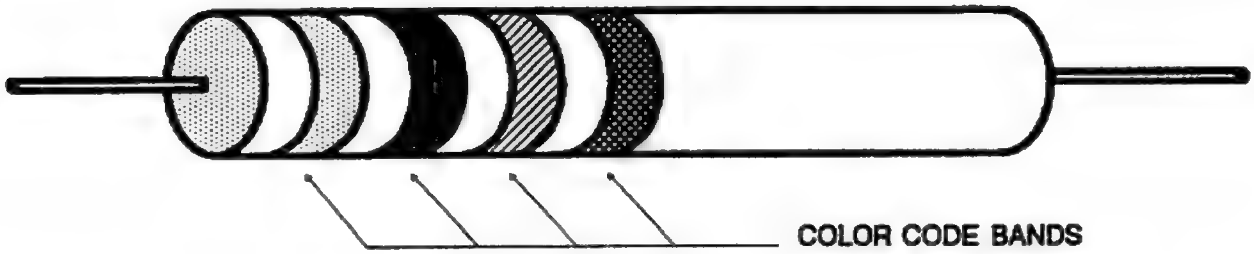
YOUR ANSWER: 1. c is correct. Ohms and watts determine the rating of a resistor.

2. b is correct. Resistor "B" is much larger than resistor "A" and physical size is the main determining factor when considering power ratings.

You can find the resistance of any resistor by using an ohmmeter, but it is easier to find the value of a resistor by its markings.

Many carbon (axial-lead) resistors have their values printed on them, but they are often mounted so that you cannot read the printed marking. Also, heat often discolors the resistor body, making it impossible to read. Some axial-lead resistors are so small that the printed marking cannot be read. To make the value of axial-lead resistors easy to read, a 12-color marking system has been established and used.

Axial-lead resistors are coded by the end-to-center band system of marking, as shown in drawing below.



In the color-code system of marking, three colors are used to indicate the resistance value in ohms, and a fourth color is used to indicate the tolerance of the resistor. By reading the colors in the correct order and substituting the corresponding numbers from the code chart, you can immediately tell all you need to know about the resistor.

Select the statement below that describes how to find the resistance of an axial-lead resistor. Circle your choice.

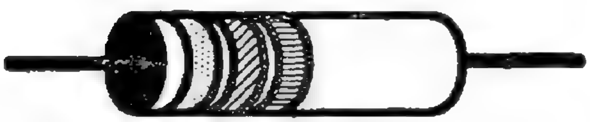
a. To find the resistance of an axial-lead resistor, a voltmeter is used.

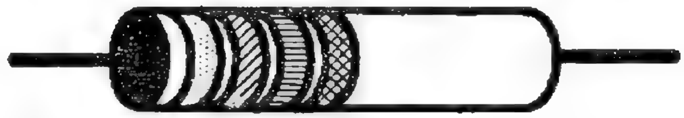
b. To find the resistance of an axial-lead resistor, an end-to-center color band system of marking is used.

(Continued Page 1-27)

YOUR ANSWER: b. is correct. To find the resistance of an axial-lead resistor, an end-to-center color band marking system is used.

Axial-lead resistors have 3 or 4 color bands, as shown in the drawings below.

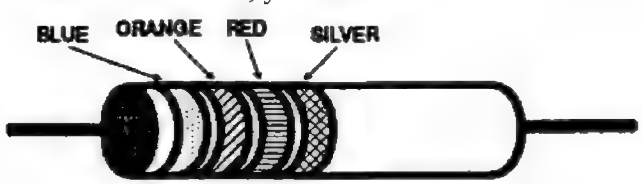




The first color band gives the first significant figure, the second band gives the second significant figure, the third color band is the multiplier, and if a fourth band appears, it will represent the tolerance of the resistor. If only three bands appear on the resistor, the tolerance will be 20% unless marked differently on the resistor. The value representing each color band of a axial-lead resistor is shown in the chart below.

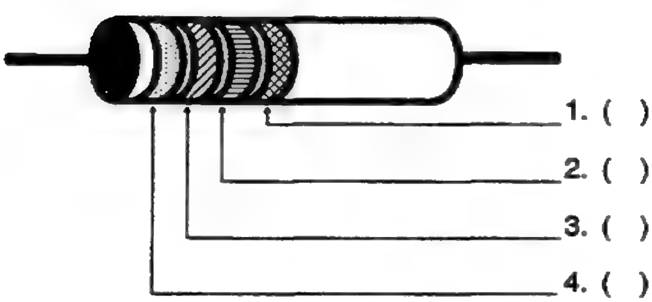
COLOR	FIG.	FIG.	MULTIPLIER	TOLERANCE
	#1	#2		
BLACK	0	0	1	
BROWN	1	1	10	
RED	2	2	100	
ORANGE	3	3	1,000	
YELLOW	4	4	10,000	
GREEN	5	5	100,000	
BLUE	6	6	1,000,000	
VIOLET	7	7	10,000,000	
GRAY	8	8	100,000,000	
WHITE	9	9	1,000,000,000	
GOLD			.1	5%
SILVER			.01	10%
NO COLOR				20%

When reading the color bands on a resistor, you read from the end towards the center.



The value of the resistor shown above is 6300 ohms ± 10%.

Match the color bands on the resistor below to the code that each band represents. Place the letter in front of each code in the space provided below the resistor.



a. 2nd significant number

b. Tolerance

c. 1st significant number

d. Multiplier (number of zeros to be added).

(Continued on Page 1-28)

YOUR ANSWER: 1. B 2. D 3. A 4. C

REMEMBER: Always read the color code from end to center. The 1st band is the first significant number, the 2nd color band is the second significant number, the 3rd color band is the multiplier (number of zeros to be added) and the 4th band, if one appears, is the percent of tolerance of the resistor.

Complete the following problems using the color code chart for assistance in finding the ohmic value and tolerances.

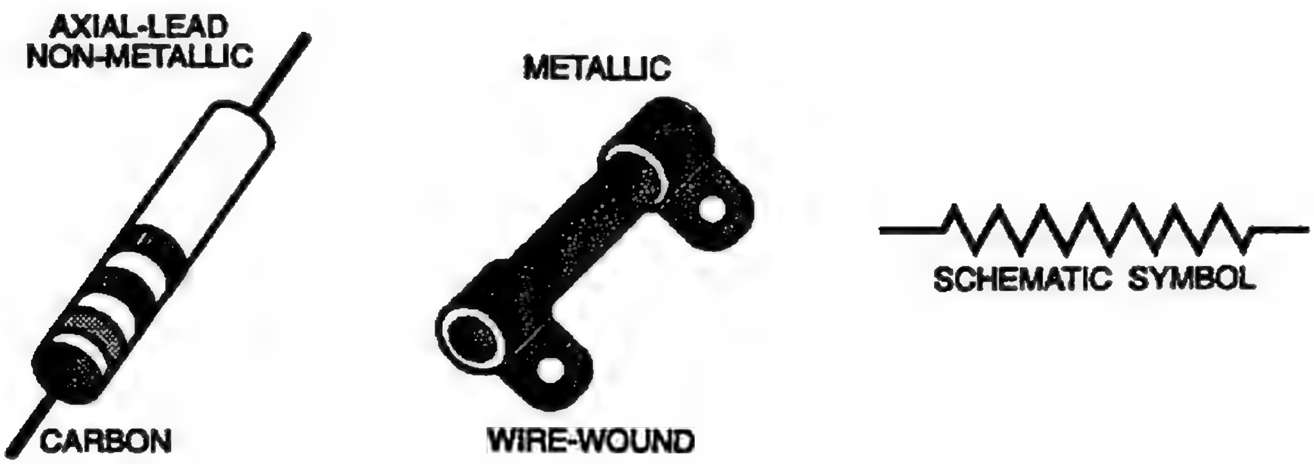
COLOR	FIG. #1	FIG. #2	MULTIPLIER	TOLERANCE
BLACK	0	0	1	
BROWN	1	1	10	
RED	2	2	100	
ORANGE	3	3	1,000	
YELLOW	4	4	10,000	
GREEN	5	5	100,000	
BLUE	6	6	1,000,000	
VIOLET	7	7	10,000,000	
GRAY	8	8	100,000,000	
WHITE	9	9	1,000,000,000	
GOLD			.1	5%
SILVER			.01	10%
NO COLOR				20%

	1st Fig. color	2nd Fig. color	Mult. color	Toler. color	Ohms value	%Tot.
1.	Red	Red	Orange	Gold	______	______
2.	Brown	Black	Brown		______	______
3.	Yellow	Green	Brown	Silver	______	______
4.	Red	Red	Brown	Gold	______	______
5.	Green	Green	White		______	______
6.	Black	Brown	Black	Gold	______	______
7.	Brown	Black	Gold	Silver	______	______
8.	Yellow	Violet	Orange	Gold	______	______
9.	Red	Black	Blue	Silver	______	______
10.	Orange	Orange	Red		______	______

(Continued on Page 1-30)

YOUR ANSWER: The two types of resistors are metallic and nonmetallic.
(From P1-17A)

Correct. Metallic and nonmetallic are the two types of resistors. Now there are three classifications of resistors. They are fixed, tapped, and variable resistors. Remember, now, these are classifications of resistors. Don't get them confused with the types of resistors. OK, let's go into the classifications one at a time. The first one is the fixed resistor. This is the most common classification. It can be either of the two types. When it is manufactured, it is made for one value of resistance, which cannot be changed. Below are two examples of fixed resistors and the electrical (schematic) symbol for a fixed resistor.



Pick the correct statement.

There are two types and three classifications of resistors. Page 1-24A

There are three types and two classifications of resistors. Page 1-19A

YOUR ANSWER:
(From P1-28)

1. 22,000 - 5%
2. 100 - 20%
3. 450 - 10%
4. 220 - 5%
5. 55,000,000,000 - 20%
6. 1 - 5%
7. 1 - 10%
8. 47,000 - 5%
9. 20,000,000 - 10%
10. 3,300 - 20%

You have finished this portion of the course. Now continue on to the examination.

EXAMINATION

Materials needed to take this examination:

Subcourse booklet; a number 2 lead pencil; and ACCP Examination Response Sheet.

Instructions:

There is only one correct answer for each item. Mark the correct answer for each item, then transfer your answers to the ACCP Examination Response Sheet, completely blacking out the lettered oval which corresponds to your section (A, B, or C). Use a number 2 lead pencil to mark your responses. Mail your response sheet in the preaddressed envelope you received with this subcourse.

Complete the following questions by choosing the most correct answer in each case:

1. A material which can readily give up and accept electrons will offer little opposition to current flow, how would you categorize this type of material?

   A. A good conductor.

   B. A good insulator.

   C. An ideal resistive material.

2. What are the four factors which determine the resistance of a conductor?

   A. Temperature, elasticity, cross-sectional area, and the type of material used.

   B. Temperature, type of material used, cross-sectional area, and the length of the material used.

   C. Temperature, elasticity, cross-sectional area, and the length of the material used.

3. What normally happens if you subject a carbon element of a circuit to heat?

   A. A decrease in resistance of the carbon element due to the negative temperature coefficient of carbon.

   B. An increase in resistance of the carbon element due to the negative temperature coefficient of carbon.

   C. A decrease in current flow through the circuit due to the negative temperature coefficient of carbon.

4. What is the most important factor when determining the specific resistance of a material?

   A. Temperature of that material.

   B. Unit volume of that material.

   C. Atomic structure of that material.

5. What do the atoms of an electrical insulator have?

   A. Many free electrons.

   B. Complete valence shells, leaving no free electrons.

   C. Complete valence shells, leaving few free electrons.

6. What type of component reaches its "breakdown point" when an applied voltage is sufficient enough to cause an intense current flow (avalanche) ?

   A. An insulator.

   B. A conductor.

   C. A resistor.

7. What type of device is placed in a circuit to oppose current flow?

   A. An insulator.

   B. A conductor.

   C. A resistor.

8. What are the two distinct types of resistors?

   A. Metallic and carbon.

   B. Metallic and wire-wound.

   C. Metallic and non-metallic.

9. What type of resistor has an extremely accurate resistance and can handle high power applications?

   A. A wire-wound resistor.

   B. An axial lead resistor.

   C. A carbon resistor.

10. What are the three classifications of resistors?

   A. Fixed, tapped, and variable.

   B. Axial lead, tapped, and variable.

   C. Tapped, fixed, and axial lead.

11. How are tapped resistors manufactured?

   A. Only with fixed taps, designed to offer predetermined resistance values.

   B. Only with adjustable taps, which permit the selection of a desired ohmic value within the range of the resistor.

   C. With either fixed or adjustable taps.

12. What does the schematic symbol  represent?

   A. Adjustable tapped resistor.

   B. Variable resistor.

   C. Either an adjustable tapped or a variable resistor.

13. When a potentiometer is used in a circuit, what does it control?

   A. The current flow in the circuit and act as a voltage divider.

   B. The amount of voltage applied to an electrical device (load) and serve as a voltage divider.

   C. The total resistance between is terminal ends thus serving as a voltage divider.

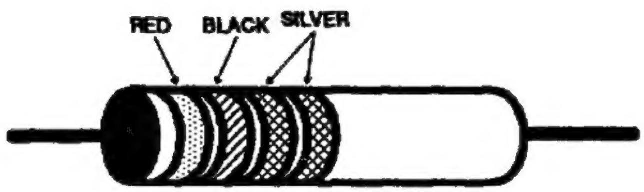
14. Which of the following statements correctly relates to the rating factors of resistors?

A. Resistors of high wattage or ohmic value are constructed larger in size than those of low wattage or ohmic value.

B. Resistor of high wattage value are constructed larger in size to effect a more efficient dissipation of power in the form of heat.

C. Resistors of high ohmic value are constructed larger in size to effect a more efficient dissipation of power in the form of heat.

Question 15 refers to the resistor shown here.



15. What is the resistance and tolerance of the axial lead resistor shown?

A. .2 ohm at 10%

B. .2 ohm at 5%

C. 20 ohm at 10%

16. Unless marked differently, what would the tolerance of an axial lead resistor coded with only three bands be?

A. 5%

B. 10%

C. 20%

17. What pure metal is the best conductor of electricity?

    A. Aluminum.

    B. Copper.

    C. Gold.

    D. Silver.

18. What are the five items affecting the choice of a conductor?

    A. Ability to be fused, cost, elasticity, melting point, and weight.

    B. Ability to be fused, cost, current capacity, elasticity, physical size, and weight.

    C. Ability to be fused, current capacity, electronic characteristics, physical size, and wattage rating.

    D. Ability to be fused, current capacity, elasticity, physical size, and wattage rating.

19. In a circuit, what is a Rheostat designed to do?

    A. Adjust capacitance.

    B. Adjust current.

    C. Adjust resistance.

    D. Adjust voltage.

20. You have a conductor four inches long and one-half inch in diameter that has a resistance of 8 OHMS. If this conductor was lengthened to 8 inches and the diameter was reduced to one-quarter of an inch, what would happen to the resistance.

    A. Decrease.

    B. Increase.

    C. Remain at 8 OHMS.